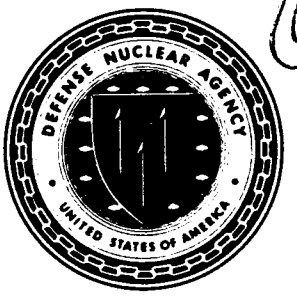
Defense Nuclear Agency
Alexandria, VA 22310-3398



DNA-TR-89-78

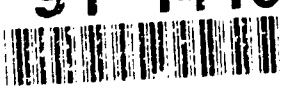
Properties of Actual and Numerical Shock and Blast-Wave Phenomena

Irvine Israel Glass
University of Toronto
Institute for Aerospace Studies
4925 Dufferin Street
Downsview, Ontario, Canada, M3H 5T6

October 1991

Technical Report

CONTRACT No. DNA 001-85-C-0368



Destroy this report when it is no longer needed. Do not return to sender.

PLEASE NOTIFY THE DEFENSE NUCLEAR AGENCY, ATTN: CSTI, 6801 TELEGRAPH ROAD, ALEXANDRIA, VA 22310-3398, IF YOUR ADDRESS IS INCORRECT, IF YOU WISH IT DELETED FROM THE DISTRIBUTION LIST, OR IF THE ADDRESSEE IS NO LONGER EMPLOYED BY YOUR ORGANIZATION.

DISTRIBUTION LIST UPDATE

This mailer is provided to enable DNA to maintain current distribution lists for reports. We would appreciate your providing the requested information.

☐ Add the individual listed to your distribution list.

☐ Delete the cited organization/individual.

☐ Change of address.

NOTE:
Please return the mailing label from the document so that any additions, changes, corrections or deletions can be made more easily.

NAME: _____

ORGANIZATION: _____

OLD ADDRESS	CURRENT ADDRESS
_____	_____
_____	_____
_____	_____

TELEPHONE NUMBER: ( ) _____

SUBJECT AREA(s) OF INTEREST:

_____	_____
_____	_____
_____	_____

DNA OR OTHER GOVERNMENT CONTRACT NUMBER: _____

CERTIFICATION OF NEED-TO-KNOW BY GOVERNMENT SPONSOR (if other than DNA):

SPONSORING ORGANIZATION: _____

CONTRACTING OFFICER OR REPRESENTATIVE: _____

SIGNATURE: _____

CUT HERE AND RETURN

Director
Defense Nuclear Agency
ATTN: TITL
Washington, DC 20305-1000

Director
Defense Nuclear Agency
ATTN: TITL
Washington, DC 20305-1000

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	911001	Technical 850930 - 881130

4. TITLE AND SUBTITLE

Properties of Actual and Numerical Shock and Blast-Wave Phenomena

5. FUNDING NUMBERS

C-DNA 001-85-C-0368
PE - 62715H
PR - A
TA - G
WU - DH009008

6. AUTHOR(S)

Irvine Israel Glass

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

University of Toronto
Institute for Aerospace Studies
4925 Dufferin Street
Downsview, Ontario, Canada, M3H 5T6

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

Defense Nuclear Agency
6801 Telegraph Road
Alexandria, VA 22310-3398
SPWE/Castleberry

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

DNA-TR-89-78

11. SUPPLEMENTARY NOTES

This work was sponsored by the Defense Nuclear Agency under RDT&E RMC Code B342085466 A G 00034 25904D.

12a. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release; distribution is unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

During the last four years almost all of the 10 tasks set out in our original proposal, and more, were completed and resulted in many publications in the open literature and in UTIAS Reports, Technical Notes and Reviews. The original problems will be listed for reference and the resulting publications are given.

14. SUBJECT TERMS

Pseudostationary Oblique-shock-wave Reflections
Interferometry Dusty-gas Shock-tube Flows
Numerical Analysis

15. NUMBER OF PAGES

14

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	SAR

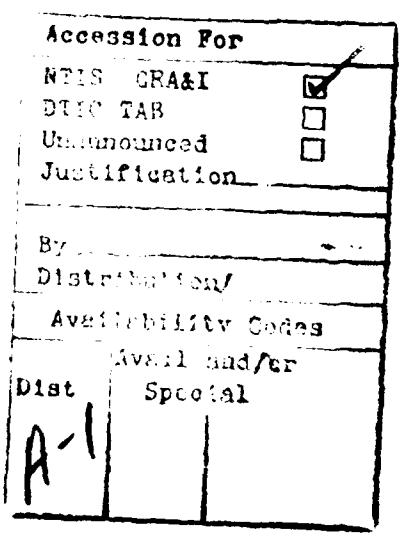
CLASSIFIED BY

N/A since Unclassified

DECLASSIFY ON

N/A since Unclassified

TABLE OF CONTENTS



SECTION 1

PROBLEMS

Problem 1

Radiation-Induced Boundary Layers — This problem was not initiated since it was done full scale in the field using helium layers and in the Ernst Mach Institute, also using helium layers, to simulate the radiation-induced boundary-layers. It would be useful to use hydrogen to simulate the heated boundary layer, if practical.

Problem 2

Dusty-Gas Boundary Layers Induced by Shock Waves — This problem was completed and resulted in 3 UTIAS Reports by B. Y. Wang and I. I. Glass, as well as a paper in the Journal of Fluid Mechanics.

Problem 3

Pitot Tubes in Dusty Flows — Very good data has already been obtained by Mr. G. D. Lock, as part of his Ph.D. thesis, under the direction of Dr. J. J. Gottlieb. His research should be completed in 1989. It will provide the first credible quantitative data on normal shock-wave structure in dusty air.

Problem 4

Passage of a Shock Wave Through a Dusty-Gas Layer — The analytical work was completed by H. Miura and i. I. Glass, and is reported in Proc. R. Soc. Lond. A385, 85-105, 1983.

Problem 5

Normal Shock-Wave Reflections in a Dusty Gas — The analytical work was completed by H. Miura, T. Saito and I. I. Glass, and is reported in Proc. R. Soc. Lond. A404, 55-67, 1986. An additional analysis was done by J. J. Gottlieb and C. E. Coskunses, "Effects of Particle Volume on the Structure of a Partly Dispersed Normal Shock Wave in a Dusty Gas", UTIAS Report NO. 295, 1985.

Problem 6

Collision of Oblique-Shock-Wave Reflections with a 90° Ramp in Air and CO_2. This work was completed and published as UTIAS Report No. 290 by J. C. Li and I. I. Glass under the same title. It was also presented at the 15th International Symposium on Shock Waves and Tubes, Stanford, California, 1986, and also as "Interaction of Oblique-Shock-Wave Reflections in Air and CO_2 with Downstream Obstacles", by H. M. Glaz, I. I. Glass, J. C. Li and P. A. Walter, at the 15th International Symposium on Shock Waves and Shock Tubes, Stanford, California, 1986.

Problem 7

Boundary-Layer Growth Along a Wedge and Its Effects on the von Neumann Paradox — This work was completed and published as "Pseudo-Stationary Oblique-Shock-Wave Reflections in Low-γ Gases - Isobutane and Sulfurhexafluoride", UTIAS Technical Note No. 267, by J. T. Urbanowicz.

Problem 8

A Resolution of the 'von Neumann' Paradox — This work was completed and presented at the 8th International Mach Reflection Symposium, UTIAS, July 12-15, 1988, under the same title by J. T. Urbanowicz and I. I. Glass, and presented by Mr. Urbanowicz.

Problem 9

Regions and Transition Boundaries in Air and SF_6 — This work was completed and has appeared in several publications.

SECTION 2

BIBLIOGRAPHY

1. J.-H. Lee and I. I. Glass, "Domains and Boundaries of Pseudostationary Oblique-Shock-Wave Reflections in Air", UTIAS Report No. 262, June 1982.
2. M. Shirouzu and I. I. Glass, "An Assessment of Recent Results on Pseudostationary Oblique-Shock-Wave Reflections", UTIAS Report No. 264, Nov. 1982.
3. R. L. Deschambault, "Nonstationary Oblique-Shock-Wave Reflections in Air", UTIAS Report No. 270, Jan. 1984.
4. J. T. C. Hu and M. Shirouzu, "Tabular and Graphical Solutions of Regular and Mach Reflections in Pseudostationary Frozen and Vibrational-Equilibrium Flows", UTIAS Report No. 283, Parts 1 and 2, Jan. 1985.
5. H. M. Glaz, P. Colella, I. I. Glass and R. L. Deschambault, "A Numerical and Experimental Study of Pseudostationary Oblique-Shock Wave Reflections in Argon and Air", UTIAS Report No. 285, Aug. 1986.
6. John Wheeler, "An Interferometric Investigation of the Regular to Mach Reflection Transition Boundary in Pseudostationary Flow in Air", UTIAS Technical Note No. 256, April 1986.
7. B. Y. Wang and I. I. Glass, "Compressible Laminar Boundary-Layer Flows of a Dusty Gas Over a Semi-Infinite Flat Plate", J. Fluid Mech., Vol. 186, 1988, pp. 223-241.
8. I. I. Glass, "The Shock Tube and Its Applications", Experiments in Fluid Mechanics, Sec. 16, Supersonic Flow, pp. 380-386, Robert A. Granger, Ed.
9. H. Miura and I. I. Glass, "Supersonic Expansion of a Dusty Gas Around a Sharp Corner", Proc. R. Soc. Lond. A415, 1988, pp. 91-105.

10. H. Miura and I. I. Glass, "Supersonic Expansion of a Dusty Gas Around a Sharp Corner", Proc. R. Soc. Lond. A415, 1988, pp. 91-105.

11. I. I. Glass and J. Kleiman, "Some PCH Aspects of Shock-Wave Research", PCH PhysicoChemical Hydrodynamics, Vol. 9, No. 1/2, 1987, pp. 93-99.

12. D. L. Zhang and I. I. Glass, "An Interferometric Investigation of the Diffraction of Planar Shock Waves over a Half-Diamond Cylinder in Air", UTIAS Report No. 322, March 1988.

13. J. T. Urbanowicz, "Pseudo-Stationary Oblique-Shock-Wave Reflections in Low Gamma Gases - Isobutane and Sulphur Hexafluoride", UTIAS Technical Note No. 267, Feb. 1988.

14. J. Kaca, "An Interferometric Investigation of the Diffraction of a Planar Shock Wave Over a Semicircular Cylinder", UTIAS Technical Note No. 269, Sept. 1988.

15. H. Honma and I. I. Glass, "Nonlinear Effects on Weak Spherical N-Waves in Air with Vibrational Excitation", Proc. R. Soc. Lond.

DISTRIBUTION LIST

DNA-TR-89-78

DEPARTMENT OF DEFENSE

ASSISTANT TO THE SECRETARY OF DEFENSE
ATTN: EXECUTIVE ASSISTANT

DEFENSE INTELLIGENCE AGENCY
ATTN: DB-TPO
ATTN: DB-6

DEFENSE NUCLEAR AGENCY
ATTN: DDIR G ULLRICH
ATTN: DFSP C MCFARLAND
ATTN: SPSD
ATTN: SPSP DR P CASTLEBERRY
ATTN: SPWE C GALLOWAY
ATTN: SPWE K PETERSEN
ATTN: SPWE T FREDERICKSON
ATTN: TDTR
2 CYS ATTN: TITL

DEFENSE TECHNICAL INFORMATION CENTER
2 CYS ATTN: DTIC/FDAB

DEPARTMENT OF DEFENSE EXPLO SAFETY BOARD
ATTN: CHAIRMAN

FIELD COMMAND DEFENSE NUCLEAR AGENCY
ATTN: FCNV

FIELD COMMAND DEFENSE NUCLEAR AGENCY
ATTN: ENIE N GANTICK
ATTN: FCNM
2 CYS ATTN: FCTT W SUMMA
ATTN: TTST E MARTINEZ
ATTN: TTST E RINEHART

STRATEGIC AND THEATER NUCLEAR FORCES
ATTN: DR E SEVIN

THE JOINT STAFF
ATTN: JKC ATTN DNA REP
ATTN: JKCS
ATTN: JLWD
ATTN: JPEM

DEPARTMENT OF THE ARMY

DEP CH OF STAFF FOR OPS & PLANS
ATTN: DAMO-SWN

HARRY DIAMOND LABORATORIES
ATTN: SLCIS-IM-TL

INFORMATION SYSTEMS COMMAND
ATTN: STEWS-NE-O K CUMMINGS

U S ARMY ARMAMENT MUNITIONS & CHEMICAL CMD
ATTN: MA LIBRARY

U S ARMY BALLISTIC RESEARCH LAB
2 CYS ATTN: SLCBR-SS-T (TECH LIB)

U S ARMY CORPS OF ENGINEERS
ATTN: CERD-L

U S ARMY ENGINEER DIV HUNTSVILLE
ATTN: HNDED-SY

U S ARMY ENGINEER DIV OHIO RIVER
ATTN: ORDAS-L

U S ARMY ENGR WATERWAYS EXPER STATION
ATTN: C WELCH CEWES-SE-R
ATTN: CEWES J K INGRAM
ATTN: CEWES-SD DR J G JACKSON JR
ATTN: J ZELASKO CEWES-SD-R
ATTN: RESEARCH LIBRARY

U S ARMY FOREIGN SCIENCE & TECH CTR
ATTN: AIFRTA

U S ARMY MATERIAL TECHNOLOGY LABORATORY
ATTN: DRXMR J MESCALL
ATTN: TECHNICAL LIBRARY

U S ARMY NUCLEAR & CHEMICAL AGENCY
ATTN: MONA-NU

U S ARMY RESEARCH DEV & ENGRG CTR
ATTN: STRNC-YSD G CALDARELLA

U S ARMY STRATEGIC DEFENSE CMD
ATTN: CSSD-H-SA
ATTN: CSSD-H-SAV
ATTN: CSSD-SD-A

U S ARMY STRATEGIC DEFENSE COMMAND
ATTN: CSSD-SA-EV
ATTN: CSSD-SL

U S ARMY WAR COLLEGE
ATTN: LIBRARY

USA SURVIVABILITY MANAGMENT OFFICE
ATTN: SLCSM-SE J BRAND

DEPARTMENT OF THE NAVY

NAVAL POSTGRADUATE SCHOOL
ATTN: CODE 1424/LIBRARY

NAVAL RESEARCH LABORATORY
ATTN: CODE 2627
ATTN: CODE 4040 D BOOK
ATTN: CODE 4400 J BORIS

NAVAL SURFACE WARFARE CENTER
ATTN: TECHNICAL LIBRARY

NAVAL WEAPONS EVALUATION FACILITY
ATTN: CLASSIFIED LIBRARY

OFFICE OF CHIEF OF NAVAL OPERATIONS
ATTN: OP 03EG

OFFICE OF NAVAL RESEARCH
ATTN: CODE 1132SM

DEPARTMENT OF THE AIR FORCE

AIR UNIVERSITY LIBRARY
ATTN: AUL-LSE

BALLISTIC MISSLE ORGANIZATION
ATTN: MCES
ATTN: MGER

HEADQUARTERS USAF/IN
ATTN: IN

PHILLIPS LABORATORY
ATTN: NTCA
ATTN: NTE
ATTN: NTE G BALADI
ATTN: NTED G GOODFELLOW
ATTN: NTED J RENICK
ATTN: NTED R HENNY
ATTN: NTED R HOFFMANN
ATTN: NTEO J QUINTANA

STRATEGIC AIR COMMAND/XPSW
ATTN: T E DENESIA XPS

STRATEGIC AIR COMMAND/XRFS
ATTN: XRFS

USAF/LEEEU
ATTN: CESA-EN

DEPARTMENT OF ENERGY

LAWRENCE LIVERMORE NATIONAL LAB
ATTN. C E ROSENKILDE
ATTN: J BELL L-316
ATTN: L-203 R SCHOCK
ATTN: L-81 R PERRETT

LAWRENCE LIVERMORE NATIONAL LABORATORY
ATTN: ALLEN KUHL

LOS ALAMOS NATIONAL LABORATORY
ATTN: REPORT LIBRARY

MARTIN MARIETTA ENERGY SYSTEMS INC
ATTN: CIVIL DEF RES PROJ

SANDIA NATIONAL LABORATORIES
ATTN: A CHABAI DIV 9311
ATTN: DIV 5214 J S PHILLIPS
ATTN: DIV 9311 L R HILL
ATTN: TECH LIB 3141

U.S. DEPARTMENT OF ENERGY
OFFICE OF MILITARY APPLICATIONS
ATTN: OMA/DP-225

OTHER GOVERNMENT

CENTRAL INTELLIGENCE AGENCY
ATTN: OSWR/NED

DEPARTMENT OF DEFENSE CONTRACTORS

AEROSPACE CORP
ATTN: H MIRELS
ATTN: LIBRARY ACQUISITION

APPLIED & THEORETICAL MECHANICS, INC
ATTN: J M CHAMPNEY

APPLIED RESEARCH ASSOCIATES
ATTN: R FLORY

APPLIED RESEARCH ASSOCIATES, INC
ATTN: J KEEFER
ATTN: N ETHRIDGE

APPLIED RESEARCH ASSOCIATES, INC
ATTN: J L BRATTON

APPLIED RESEARCH ASSOCIATES, INC
ATTN: R FRANK

APPLIED RESEARCH ASSOCIATES, INC
ATTN: J L DRAKE

BDM INTERNATIONAL INC
ATTN: E DORCHAK
ATTN: J STOCKTON

CALIFORNIA RESEARCH & TECHNOLOGY, INC
ATTN: J THOMSEN

CARPENTER RESEARCH CORP
ATTN: H J CARPENTER

E-SYSTEMS, INC
ATTN: TECH INFO CTR

FLUID PHYSICS IND
ATTN: R TRACI

GEO CENTERS, INC
ATTN: B NELSON

IIT RESEARCH INSTITUTE
ATTN: DOCUMENTS LIBRARY
ATTN: M JOHNSON

INFORMATION SCIENCE, INC
ATTN: W DUDZIAK

INSTITUTE FOR DEFENSE ANALYSES
ATTN: CLASSIFIED LIBRARY

KAMAN SCIENCES CORP
ATTN: L MENTE
ATTN: LIBRARY
ATTN: R RUETENIK

KAMAN SCIENCES CORP
ATTN: F SHELTON
ATTN: LIBRARY B KINSLOW

KAMAN SCIENCES CORP
ATTN: D MOFFETT
ATTN: DASIAC
ATTN: E CONRAD

KAMAN SCIENCES CORPORATION
ATTN: DASIAC

LOCKHEED MISSILES & SPACE CO, INC
ATTN: TECH INFO CTR

LOGICON R & D ASSOCIATES
ATTN: B KILLIAN
ATTN: E FURBEE

LTV AEROSPACE & DEFENSE COMPANY
2 CYS ATTN: LIBRARY EM-08

MCDONNELL DOUGLAS CORPORATION
ATTN: R HALPRIN

MOLZEN CORBIN & ASSOCIATES, P.A.
ATTN: TECHNICAL LIBRARY

NEW MEXICO ENGINEERING RESEARCH INSTITUTE
ATTN: J JARPE
ATTN: N BAUM

NICHOLS RESEARCH CORPORATION
ATTN: R BYRN

PACIFIC-SIERRA RESEARCH CORP
ATTN: H BRODE

PHYSICAL RESEARCH INC
ATTN: D MODARRESS

R & D ASSOCIATES
ATTN: C K B LEE
ATTN: D SIMONS
ATTN: LIBRARY
ATTN: T A MAZZOLA

R & D ASSOCIATES
ATTN: G GANONG
ATTN: T EDWARDS

R & D ASSOCIATES
ATTN: E FURBEE
ATTN: J WEBSTER

RAND CORP
ATTN: B BENNETT

S-CUBED
ATTN: C PETERSEN
ATTN: G SCHNEYER
ATTN: J BARTHEL
ATTN: K D PYATT JR
ATTN: P COLEMAN
ATTN: T PIERCE

S-CUBED
ATTN: C NEEDHAM

SCIENCE APPLICATIONS INTL CORP
ATTN: C HSIAO
ATTN: G T PHILLIPS
ATTN: H WILSON
ATTN: TECHNICAL REPORT SYSTEM

SCIENCE APPLICATIONS INTL CORP
ATTN: DIV 411 R WESTERFELDT

SCIENCE APPLICATIONS INTL CORP
ATTN: J WILLIAMS

SCIENCE APPLICATIONS INTL CORP
ATTN: J COCKAYNE
ATTN: R SIEVERS
ATTN: W LAYSON

SCIENCE APPLICATIONS INTL CORP
ATTN: K SITES

SCIENCE APPLICATIONS INTL CORP
ATTN: G BINNINGER

SCIENCE APPLICATIONS INTL CORP
ATTN: R ALLEN

SRI INTERNATIONAL
ATTN: D KEOUGH
ATTN: DR B S HOLMES
ATTN: J SIMONS
ATTN: M SANAI

TECHNICO SOUTHWEST INC
ATTN: S LEVIN

THE TITAN CORPORATION
ATTN: K KREYENHAGEN
ATTN: LIBRARY
ATTN: M ROSENBLATT

TRW INC
ATTN: D AUSHERMAN
ATTN: M SEIZEW
ATTN: R BATT

TRW SPACE & DEFENSE SECTOR
ATTN: HL DEPT LIBRARY
ATTN: W WAMPLER

UNIVERSITY OF TORONTO
2 CYS ATTN: I I GLASS

WASHINGTON STATE UNIVERSITY
ATTN: PROF Y GUPTA

WEIDLINGER ASSOC, INC
ATTN: H LEVINE

WEIDLINGER ASSOCIATES, INC
ATTN: T DEEVY

WEIDLINGER ASSOCIATES, INC
ATTN: I SANDLER
ATTN: M BARON